Does the toe-touch test predict hamstring injury in Australian Rules footballers?

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This prospective cohort study evaluated the relationship of hamstring and lumbar spine flexibility to hamstring injury. Sixty-seven senior male Australian Rules footballers were videotaped while performing a toe-touch test from erect standing. The Peak Motion Measurement System was used to obtain measurements of end range hip flexion, lumbar flexion, toe-touch distance (TTD) and the ratio of lumbar spine flexion to hip flexion. Over the following football season, eight subjects (11.9 per cent) sustained a hamstring strain. Results showed no significant difference between the hamstring injured or uninjured players for any of the measured variables with no variable able to predict the likelihood of injury ($p > 0.05$). In this cohort, the toe-touch test would not appear to be a useful screening tool to identify footballers at risk for hamstring strain. **[Bennell K, Tully E and Harvey N (1999): Does the toe-touch test predict hamstring injury in Australian Rules footballers? *Australian Journal of Physiotherapy* 45: 103-109]**

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Introduction

Hamstring strain is a common injury in Australian Rules football (Seward et al 1993, Shawdon and Brukner 1994). At the elite level, hamstring strains are not only the most common injury with a prevalence of 14 per cent but also account for the most playing time missed (Seward et al 1993). Despite intense rehabilitation, recurrence rates are as high as 34 per cent (Seward et al 1993). Hamstring strains are less common at the amateur level than the elite level, which may be due to less rigorous training, slower paced sprints and less powerful kicking (Shawdon and Brukner 1994). Despite comprehensive stretching and strengthening programs throughout pre-season training and intense rehabilitation during the season, hamstring injuries continue to debilitate many athletes. There has been much speculation about the cause of hamstring strain in athletes (Jonhagen et al 1994, Liemohn 1978, Worrell et al 1991, Worrell and Perrin 1992). While inadequate muscle strength, muscle imbalance and improper running technique have been suggested as possible causative factors, this paper will focus on the relationship between hamstring injury and flexibility of the hamstring muscles and lumbar spine.

In Australian Rules football, acute hamstring strains commonly occur while sprinting, particularly at foot strike or during the last part of the swing phase when the two joint hamstring muscles are lengthened over both hip and knee joints (Garrett 1990, Worrell et al 1994, Zarins and Ciullo 1983). At this stage the hamstrings are contracting eccentrically to decelerate thigh flexion and knee extension (Coole and Giek 1987). The high force developed during an eccentric muscle contraction in running must be absorbed by the active, contractile tissue and the passive, series elastic component of the muscle (Garrett et al 1987, Garrett 1990, Safran et al 1988). As the muscle lengthens during an eccentric contraction, the passive series elastic component increases its role in energy absorption; a more extensible passive component enables the musculoskeletal system to absorb energy over a greater distance and for a longer period of time, whereas limited muscle flexibility reduces the force absorption capability of the muscle (Wilson et al 1991, Worrell et al 1994). Thus greater flexibility may well reduce the incidence of muscle injury as a result of increased absorption of energy decreasing the load on working muscles.

Reduced range of movement in the lumbar spine has also been suggested as a factor contributing to hamstring injury during football (Brukner and Khan 1994). During the activities of sprinting, jumping, bending to retrieve a low ball and kicking, the hips and lumbar spine form a series related system of joints which move together in a co-ordinated manner. It has been demonstrated that altered mobility of one of the component links in a multi-joint system can produce compensatory movement in another which

Table 1. Mean (SD) for toe-touch distance, lumbar spine flexion, hip flexion and lumbo-femoral ratio in players with and without a hamstring strain.

Measurement	Hamstring strain $n = 8$		No hamstring strain $n = 59$		Mann Whitney U test
Toe-touch distance (cm)	1.3	(9.1)	2.6	(9.2)	U = 209; p =0.76
Lumbar spine flexion (degrees)	43.6	(9.6)	43.5	(7.9)	U = 219; p = 0.92
Hip flexion (degrees)	79.7	(10.3)	77.8	(10.9)	U = 213; p = 0.82
Lumbo-femoral ratio	0.56	(0.16)	0.57	(0.14)	U = 218: p = 0.90

may lead to pathology, pain and dysfunction (Thurston 1985).

The results of research investigating the role of flexibility in hamstring injury is conflicting. While there is only one study looking at flexibility of Australian Rules footballers (Orchard et al 1997), others have investigated athletes in sports with similar skills, that is, short bursts of sprinting and some kicking (Burkett 1970, Ekstrand and Gillquist 1982, Hennessy and Watson 1993, Jonhagen et al 1994, Liemohn 1978, Worrell et al 1991). Many of the studies are cross-sectional designs comparing flexibility in athletes who have sustained a previous hamstring injury with a non-injured group. However, using such research designs means there is no way to distinguish if muscle tightness is the result of, or the cause of, the injury. Even amongst the prospective cohort studies where flexibility is measured before the injury occurs, results are contradictory.

The methods most commonly used to measure hamstring flexibility in these studies have been either the straight leg raise or the sit-and-reach test. These provide a reliable measure of flexibility in the sagittal plane, but have been criticised for their failure to differentiate hip from spinal motion. To further evaluate the relationship of flexibility and hamstring injury, we used computer aided video analysis of toe-touching from upright standing (Tully and Stillman 1997). Toe-touching is similar to the sit-and-reach test but enabled discrete measurement of hip and lumbar spine flexion angles as well as toe-touch distance at the limit of the movement. The results of this research will assist in clarifying the role of flexibility as a predictor of hamstring injury in football.

Method

Research design An observational, analytic, prospective cohort study design was used.

Subjects Sixty-seven male subjects were recruited for this study from senior level Australian Rules football teams (four professional and four amateur teams) in Melbourne. These were a sub-group of players from a larger study (Bennell et al 1998). The mean (SD) age was 22.7 years (3.44; range, 18 to 31), the mean height 184.5cm (6.36; range, 170 to 198) and the mean weight 83.9kg (7.27; range, 67 to 101). The study was approved by the Human Research Ethics Committee at The University of Melbourne and all subjects provided written informed consent.

Procedure Testing took place during pre-season from January to April 1996. Each subject completed a questionnaire about previous lower limb injuries. Subjects were requested not to participate in any vigorous exercise in the four hours preceding testing. A standardised warm-up was completed prior to testing, consisting of five minutes of stationary cycling and quadriceps, hamstring and calf muscle stretches held for 60 seconds each.

Computer analysis of videotape images of toe-touching with knees extended from erect standing was used to measure toe-touch distance and end range hip and lumbar spine flexion angles. Six reflective markers were positioned on the subjects thoracolumbar spine, pelvis and lateral thigh at T10, L1, mid-posterior superior iliac spine (PSIS), anterior superior iliac spine (ASIS), 2/3 thigh (Th) and lateral femoral condyle (LFC) as outlined by Tully and Stillman (1997, Figure 1a). A scaling rod was placed close to the subject for calibration during video

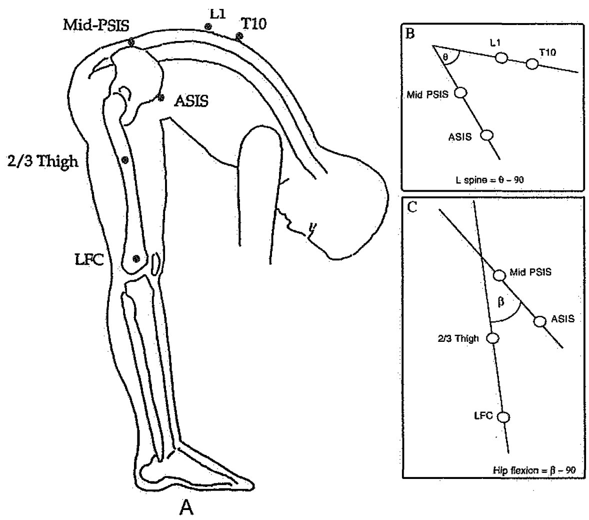

Figure 1:

A: Placement of reflective markers on subjects during toe touching. B: Measurement of lumbar spine angle. C: Measurement of hip flexion angle.

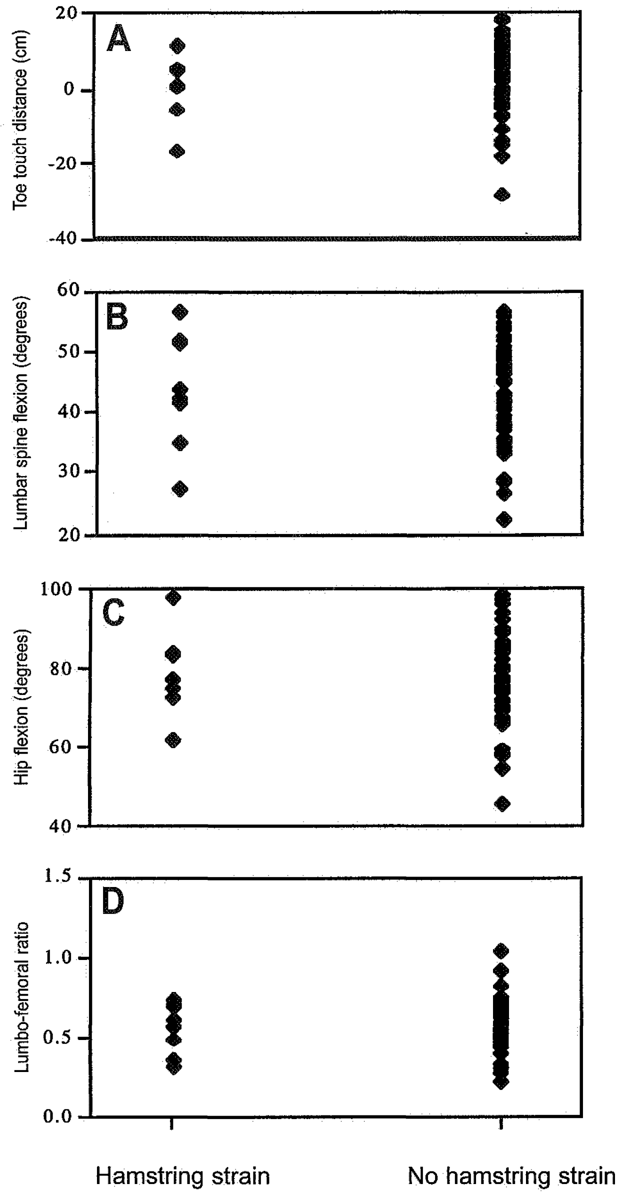

Figure 2: Individual scores for players with and without a hamstring strain. (A) Toe-touch distance. (B) Lumbar spine flexion. (C) Hip flexion. (D) Lumbo-femoral ratio.

analysis. For the toe-touch test, subjects stood on a raised platform with feet together and knees straight, and were instructed to bend forward at a comfortable pace and stretch the fingertips of both hands towards their toes and beyond if possible.

Each subject was videotaped from the right lateral aspect, performing three warm-up trials at the subject's self selected pace, with appropriate technique correction. The fourth attempt was used for analysis, unless the subject persisted with poor technique, in which case another toe-touch manoeuvre was completed.

Following manual digitisation of the reflective markers displayed on a single frame of the videotape at the limit of the test movement, the Peak software program (Peak Performance Technologies Incorporated; Englewood, CO) was used to calculate toe-touch distance (TTD), hip and lumbar flexion angles. Subsequently the lumbo-femoral ratio was also calculated for each subject.

Toe-touch distance was determined by measuring the distance from the end of the right middle fingertip to the tip of the toes. A negative value indicated failure to reach the toes.

The angle of lumbar spine flexion was determined by drawing a straight line between reflective markers on T10 and L1 (to form a tangent with the vertebral column) and a straight line between the mid PSIS and ASIS reflective markers (representing the sagittal plane of the pelvis) (Figure 1B). The angle between these two lines when extended (β) minus 90 degrees constituted the angle of lumbar flexion.

The angle of hip flexion was calculated as the angle between the intersections of the lines representing the plane of the pelvis and the long axis of the thigh (β), minus 90 degrees (Figure 1C).

The lumbo-femoral ratio was calculated by dividing the lumbar flexion angle by the hip flexion angle.

Diagnosis of hamstring strain Subjects were monitored over the 1996 football season (up to 32 weeks, different for each competition) for any hamstring problems. Diagnosis of a hamstring strain was made by medical staff at each player's club during the 1996 season. The strain was only included if it met the following criteria: (1) sudden onset of pain in the hamstring muscle during a match or training; (2) pain in the hamstring muscle with contraction of the muscle and with stretching; (3) tenderness on palpation; and (4) caused the player to miss an official match. The medical staff were also encouraged to obtain an ultrasound confirming diagnosis of a hamstring strain.

Statistical analysis Analysis of the data was completed using Statview SE+ Graphics Software (Abacus Concepts Inc., Berkeley, USA). The mean and standard deviation for TTD, hip flexion, lumbar flexion and lumbo-femoral ratio were calculated for both groups. A Mann Whitney U test was then used to calculate any differences between injured and non-injured athletes for each parameter as the data were not normally distributed. Logistic regression was used to evaluate whether the measures of TTD, hip flexion and lumbar flexion could predict the likelihood of hamstring injury. All statistical results were considered significant at an alpha level of $p < 0.05$.

Results

Of the 67 subjects, eight (11.9 per cent) sustained a clinically diagnosed hamstring strain during the 1996 football season. Six (75 per cent) of these strains were confirmed on ultrasound. Mean (SD) values for toe-touch distance, lumbar spine flexion, hip flexion and lumbo-femoral ratio for both hamstring injured and uninjured players are provided in Table 1, while individual player scores are shown in Figure 2. There was no significant difference between groups for any of these variables ($p > 0.05$). The variability of the data was also similar between the two groups, as shown by the similar sized standard deviations. The results of the logistic regression also showed that none of the variables was a significant predictor of the likelihood of hamstring injury in this cohort ($p > 0.05$).

Discussion

This study confirmed that hamstring strains are a common injury in Australian Rules football. The number of players sustaining a hamstring strain, 11.9 per cent, was similar to the rates described in previous studies of football injuries at this level: 8 per cent at the amateur level (Shawdon and Brukner 1994) and 14 per cent at the elite level (Seward et al 1993).

The results showed no association between pre-season flexibility testing using the toe-touch test and hamstring strains during the following football season. There were no significant differences between hamstring injured and non-injured athletes in TTD, end range hip and lumbar spine flexion or lumbo-femoral ratio nor were these variables predictive of hamstring injury suggesting that neither poor nor excessive flexibility contributed to hamstring strain in this cohort. Due to the non-significant results, there appears to be no link between the ability to toe-touch and the risk of hamstring strain in male senior level footballers.

While there have been no other studies using toe-touching as a flexibility measure to predict hamstring strains, our results are similar to those of Orchard et al (1997) who found no correlation between pre-season sit-and-reach testing and rate of hamstring strain in their study of elite Australian Football League footballers. In fact, five of their six hamstring injured players had sit-and-reach values which were close to the group mean. While the toe-touching and sit-and-reach tests are both bilateral forms of assessment, thus insensitive to side-to-side differences, these results indicate that there is no relationship between hamstring strain and the length of the shorter muscle.

Studies reporting that hamstring injured athletes are less flexible have tended to be retrospective in design and have used the straight leg raise test as a measure of flexibility. The tightness post injury in these studies is possibly not a predisposing factor to the initial hamstring strain but may be a result of the strain. Evidence demonstrates that areas of inflammation and adhesion occur following muscle injury (Garrett et al 1987, Nikolaous et al 1987) which may have a detrimental effect on muscle flexibility.

Furthermore, the straight leg raise uses the angle of the thigh against a vertical or horizontal reference. This measure is confounded by posterior rotation of the pelvis as the leg is raised (Bohannon 1982, Bohannon et al 1985). As the pelvis rotates posteriorly during hip flexion in the straight leg raise test, the ischial tuberosity and the origin of the hamstring muscles moves in the same direction as the muscle insertion, so that there is little alteration in muscle tension. At the same time, lumbar flexion in conjunction with hip flexion and knee extension increases neural tension. It is evident that the SLR may be more indicative of neural extensibility than hamstring muscle length. In comparison with the toe-touch tests, the SLR test does not permit angular measurement of lumbar spine flexion in addition to hip flexion.

It has been suggested that neural extensibility may play a role in predisposing to hamstring injury (Turl and George 1998). In cases where neural pathology produces altered tension in the hamstring muscles, the intensity or synergy of muscle contraction may be altered and injury to the musculotendinous unit may occur. It is possible that momentary stretch on irritated neural tissues may cause a protective reflex contraction in the hamstring muscles, resulting in an unco-ordinated agonist-antagonist action. Certainly, measurements obtained from the toe-touch test include a component of neural extensibility. However, variations in cervical position (Maitland 1985) and the degree of ankle dorsiflexion during the test (Gajdosik et al 1985) may affect the contribution of neural extensibility to the test results. Since the toe-touch test (or the SLR) on its own may be insufficient to reveal a neural component, or may fail to differentiate between neural and hamstring muscle extensibility, a specific test of neural tension such as the slump test (Kornberg and Lew 1989, Maitland 1985) would be required to fully investigate the relationship between flexibility and hamstring injury.

There are several possible explanations for the failure of this research to establish a relationship between flexibility and subsequent hamstring injury. The choice of an end range measure of flexibility such as the toe-touch test may not have been the most appropriate test for the prediction of hamstring injury. Van Wingerden et al (1995) reported that increased hamstring muscle stiffness altered the lumbo-pelvic relationship only in the first one-third of the toe-touch test and not in the final position.

Although frequently strained during an eccentric contraction in late swing, the hamstring muscles may not necessarily be at the limit of their functional length at the time of injury. Instead, a test of muscle stiffness or compliance at mid to outer range may be more pertinent (Magnusson 1998).

While the ratio of lumbar spine to hip movement was calculated for the end range toe-touch position, video analysis of the dynamic relationship existing between movement of the lumbar spine, pelvis, and hip joints during the toe-touch manoeuvre, or a more functionally related activity such as treadmill running, may have been enlightening. During running, precise control of the lumbar spine and pelvis is needed to ensure optimal length of the muscles driving the leg, including the two joint hamstring muscles. During sprinting, alterations in the co-ordination of lumbo-pelvic and leg movement may affect the ability of the muscles to respond to the demands of the activity resulting in hamstring strain. In addition, while the focus of this research has been on the relationship between flexibility and subsequent hamstring injury, flexibility is unlikely to account for those hamstring strains which occur during the take off segment of the support phase of running in Australian Rules football, or during kicking, where it appears to be the stance leg which is most commonly injured.

The number of footballers who sustained a strain during the season was relatively small and this may have limited the power of this study to detect a relationship if one existed. Nevertheless, there did not appear to be any trends which might have suggested a possible relationship with scores between groups almost identical. The mean TTD score indicated that on the whole, the footballers were relatively flexible, which may be due to the inclusion of regular stretching in training regimens. A relationship may in fact exist between injury and flexibility outside the range of flexibility scores measured in this study.

It is evident that risk factors for muscle injury in sport are likely to be multifactorial. In addition to flexibility, there are other intrinsic factors which may have predisposed to hamstring strain in this cohort of footballers including the relative strength of quadriceps and hamstring muscles and co-ordination of agonist-antagonist muscle contraction. Extrinsic factors such as training regimen, playing surfaces, warm-up, prior to playing, how warm the player was immediately prior to injury, and the intensity of effort should also be considered.

Conclusion

This study showed no relationship between pre-season results of toe-touch test measurements and hamstring strains sustained during the football season. There was no difference in TTD, end range hip and lumbar spine flexion and lumbo-femoral ratio between hamstring injured and non-injured athletes, and these variables were unable to predict the likelihood of injury. Further research needs to consider strength, neural tension, and other measurements of intrinsic muscle flexibility during pre-season testing, to establish possible risk factors for hamstring strains. This would allow for more effective preventative programs.

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